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MR. LANE
ON THE ADMISSION OF AIR INTO THE VEINS.



ON THE ADMISSION OF AIR INTO THE VEINS.

By G. F. LANE, Esq.

Read on Thursday, February 28, 1850.

My attention was directed to the subject of "air in veins" from having been called to assist at a surgical operation during the course of which the patient became an unfortunate illustration of the effects of even a small quantity of air in the circulation, when suddenly introduced through a wounded vein. Though it would be impossible to determine with anything like accuracy the amount of air which entered, yet, from the small size of the opening, and the strict attention directed to the spot at the time, the quantity must have been very inconsiderable. The sudden accession of symptoms in this case, and the rapidly fatal termination of many others, render it unnecessary for me to allude to the importance of the subject, and at the same time serve in some measure to explain the meagre detail which is evident in cases of this kind, recorded as having occurred in the human subject.

Mrs. Simkiss, æt. 46, a married woman, of light complexion, usually enjoying good health, and mother of eight children; while suckling the last two she suffered pain in her left breast, and, on weaning the youngest six years ago, a small hard lump made its appearance in the axilla, which increased and became so painful that she desired its removal. On the 7th of February, 1848, Mr. Gay performed the operation. The patient was seated in a chair, and rendered insensi-

ble by the administration of chloroform. Having divided the integuments across the floor of the axilla, a large glandular mass was brought into view, carefully dissected from the surrounding parts, and excised: three small arteries were tied, and scarcely any blood was lost. At the bottom of the wound there remained a portion of diseased structure, which it was deemed advisable to remove. To effect this, the diseased tissue was seized with a tenaculum and drawn down: the arm being raised, to allow of its being distinctly seen. In dissecting it out, a tributary branch of the axillary vein was wounded near the chest: the opening was small: air was seen both by Mr. Gay and myself to enter the orifice, accompanied with a peculiar noise sufficiently loud to be audible to all present: the sound being quite characteristic of the entrance of air and fluid through a contracted opening, or of air drawn through fluid,—something between gurgling and hissing, and resembling the sound heard when, in drawing the last portion of a fluid from a vessel into a syringe, some air accompanies it. A great change was immediately noticed in the condition of the patient: the powers of the circulation sank; the woman, who had nearly recovered from the influence of chloroform, (the effect of which had not been kept up as the operation was nearly concluded,) became exceedingly faint and sank down in the chair.

Mr. Gay instantly detached the portion of gland he was engaged in removing at the time, and applied pressure above the opening in the wounded vein. The pulse was now imperceptible; the face deadly pale. Brandy was freely given, the wound closed as speedily as possible, the arm brought to the side, and the woman placed in the recumbent posture. The surface of the body became cold, and the patient seemed scarcely to breathe. Ammonia was held to the nostrils; bottles of hot water applied to the feet; the legs and arms were rubbed continuously; the feet and hands immersed in hot water; hot brandy and water poured down the throat in considerable quantities, and subsequently some sulphuric ether. After the lapse of an hour and a half, during which these measures were continued, the pulse at the wrist could be detected beating regularly, and the woman began to regain her consciousness, which she had lost immediately after the entrance of air into the vein. After this she fell into hysterical fits, which soon passed off again, and after two hours she was placed on the bed so far recovered as to admit of a compress being applied, and the arm bandaged to the side; the pulse beating 80 in a minute, regular, but feeble. She was ordered Sp. Am. Aromat. out of Mist. Camphoræ every four hours.

At 7 P.M. (three hours after the operation) she complained of pain and stiffness about the shoulder, doubtless from the tightness of the bandage. Pulse risen to 100.—Ordered ten minims of Battley's Liq. Opii Sedativus at bedtime.

8th (the following day)—The report is that she dozed occasionally during the night, but still complains much of the shoulder. There has been no bleeding besides a little which took place after the application of the bandages, and just sufficient to stiffen them. Tongue furred; pulse 98, regular, of moderate volume; skin rather hot; bowels relieved.—Iced water to be applied to the part, and a draught containing acetate of ammonia and nitrate of potash out of camphor mixture every four hours.

9th.—Dozed frequently during the night, but woke up with pain in the shoulder. Pulse 104, regular and fuller; tongue coated with a brownish white fur, and inclining to dry; bowels

again relieved. — Continue the mixture.

10th.—Slept more soundly; pulse 100, soft and full; wound discharging. A slight cough is observed to-day.

11th.—She was seized with sickness last night, followed by rigors, which lasted for two hours. The bandages being removed, the wound is found looking healthy. The ligatures were then removed, strapping applied, and the arm lightly bandaged to the side.—Draught to be continued.

She continued from this time to progress favourably without any bad symptom, and on the 28th of the month the wound had quite healed.

On calling on her recently, with a view of ascertaining whether she had been sensible of anything during the operation, she stated, quite *sua sponte*, that she heard Mr. Gay call for an instrument "to hook down something;" that just before she became insensible "something went 'bubble bubble' under the arm, and shot quite cold across her breast;" and that, just as she "went off," she got quite cold all over," and knew nothing till she recognised me sitting by her side. There has been no return of the disease, and her general health has been better since than before the operation.

A case very similar to the above has been related by Mr. Bransby Cooper.* While amputating an arm at the shoulder, a peculiar hissing noise was heard, like air escaping from a narrow-necked bottle; and the patient, an emaciated girl, æt. 19, immediately fell into a state of collapse threatening dissolution, during which the following conditions were observed:—The countenance was deadly pale; the pupils fixed, and inobedient to light; pulse small and fluttering, although at intervals regular; respiration hurried, feeble, and at irregular intervals, attended with a deep sigh.—She partially recovered after the lapse of an hour, during which the following remedies were used:—The patient was placed in a horizontal posture; the flap brought over the wound, and held by plaster; cold water was thrown on her face; ammonia held to her nostrils; and a sponge filled with wine to the lips. She quite recovered from this operation, but subsequently died of disease of the spine.

* Med.-Chir. Trans. vol. xxvii.

The earliest experiments of injecting air into veins were performed by Wæpfer, upwards of two centuries ago, and after him by Redi, Heyde, Brunner, Morgagni, and others, with the same results. Besides certain symptoms common to each of them, to be presently mentioned, it was ascertained that death occurred most suddenly when the air was injected with rapidity and force; and finding much air mixed with blood in the cavities of the heart, its contractions were supposed by these experiments to be hindered by the distension of its walls, much in the same way as urine prevents the contraction of the bladder in certain cases when accumulated in large quantities within its walls. The first experiments made in this country were by Dr. Langrish,* in 1746: he injected air into the jugular vein—it speedily proved fatal, and after death, finding the right cavities of the heart distended with air and a little frothy blood, and the left collapsed, he believed that death was caused by the resistance which the air afforded to the return of blood through the *venæ cavæ*.

From this period the subject appears to have excited no attention till Bichat published his “*Recherches Physiologiques*,” in 1811, in which he made some statements as to the quantity of air required to prove fatal, and advanced an opinion that death was caused by the irritation of air in the vessels of the brain. Immediately afterwards, Nysten† published his experiments, showed from them the error into which Bichat had fallen, and was led to the same conclusion to which Morgagni had arrived—viz. that the effects of a large quantity of air injected suddenly into the veins proved fatal, by distending the right cavities of the heart, and preventing their contraction so as to propel the blood through the capillaries of the lungs. Though the experiments of killing animals by injecting air into the circulation bear an ancient date, yet before the commencement of the present century no case is recorded of the entrance of air into a vein during a surgical operation. It was observed on the continent in 1806, by Verrier, whilst bleeding a horse, and in 1818 by M. Beauchêne, in a human subject, at the

Hospital St. Antoine, whilst operating on the base of the neck. After the paper of Magendie's, in the *Journal de Physiologie*, in 1821, the question was considered at greater length, and several cases are related as having occurred in different parts, some of which were doubtless unfounded.* In 1839 a sharp discussion was held at the Royal Academy of Medicine, Paris, upon a case related by M. Amussat, in which alarming symptoms of dissolution came on in the course of an operation on the neck, and attributed by him to the entrance of air into a vein. Amongst others, Velpeau was most sceptical of the alleged cause of the symptoms that supervened, grounding his objections on the difference which was manifested in the symptoms produced in experiments upon animals, and similar cases in the human subject. Till 1839, if we except four cases, in which air entered accidentally, its introduction in the various experiments had always been accomplished by injection, but Amussat now first demonstrated its entrance under favourable circumstances during inspiratory efforts. Since the time of Dr. Langrish, the authors who have written upon the subject in this country are Dr. Cormack,† Sir C. Bell,‡ Mr. Erichsen,§ and Dr. John Reid.|| We propose to examine some of the results to which the experiments alluded to have led; and first, it is a matter of interest to know by what agency air enters certain veins when opened in the living subject, in the region termed by Amussat “*espace dangereuse*.”

In expansion of the thorax during inspiration, the blood in the *venæ cavæ* and their tributary branches is accelerated in its course to the right auricle by a species of suction, which admits of simple explanation. The atmospheric pressure on the parietes of the thorax being relieved somewhat by the action of the inspiratory muscles, the ordinary pressure on the vessels without, combined with a tendency to a vacuum around those within, favours the return of blood along the veins immediately emptying into the chest: we should infer that these movements influence the venous current more than the ar-

* See Case, *Leçons Orales de Clinique Chirurgicale*, par M. Velpeau, tome iii.

† Prize Thesis, Edinburgh, August 1837

‡ Practical Essays, 1841.

§ Edinburgh Med. & Surg. Jour. vol. lxi. 1844.

|| Physiological Researches, 1848.

* Physical Experiments on Brutes, 8vo. 1746.

† Recherches de Physiologie et de Chimie Pathologique, 1811.

terial, inasmuch as the walls of the veins being less firm and resisting than those of the arteries, are more susceptible of such agencies, and the contraction of the chest being passive while its expansion is effected by muscular effort; these influences, though not marked in ordinary, are very manifest in forced respiration.

That the systole and diastole of the right auricle exert some influence upon the venous current may be observed in the regurgitation which may be seen, under favourable circumstances, at the base of the neck. It is stated by Magendie,* that during dilatation of the right auricle blood is drawn towards that cavity, and that when the auricular dilatation and expansion of the chest take place together, blood flows uninterruptedly along the jugulars, and the auricle is speedily filled. To prove the effect of inspiration on the venous current, Magendie introduced a gum-elastic tube into the jugular vein and superior cava of an animal, even to the auricle, and found that with each expiration alone did blood escape from the extremity of the tube, and with each inspiration air was admitted. By similar experiments he demonstrated a small amount of aid rendered to the arterial current by the respiratory movements: and that the venous current is not only influenced by forces acting directly on it, but also through the medium of the arteries; and by appending a hæmadynamometer these forces could be estimated.

It is stated by Poiseuille† that the spontaneous entrance of air into a wounded vein cannot take place further from the walls of the chest than two or three inches—*i. e.* as far as the venous pulse extends; that beyond this the atmospheric pressure between the opening and the heart is unfavourable to the production of the phenomena: but Blandin is of opinion (and a reference to cases fully confirms it) that certain circumstances exist capable of extending the distances at which air may enter a vein; such, for example, as a tube passed along a vein into the chest, adhesion of the walls of a vein to morbid growths, producing a “canalization” of the vessels said to be favourable to the admission of air: hence the great

danger in operating about the base of the neck, from the connection of the veins with the cervical fascia; and not only so, but the co-operative contraction of the platysma myoides, sterno-mastoid, and anterior part of the trapezius during powerful inspiration, must, according to Sir C. Bell, by keeping the cervical veins patent, also favour the entrance of air into them. The comparative emptiness of the vessels after hæmorrhage may account for the greater liability to the occurrence of this accident which is said to exist under these circumstances.

The passage of air as far as the left side of the heart is rare, and does not occur unless a considerable quantity has been injected. Blandin affirms that it is constantly produced when air has been thrown in with rapidity: this statement is open to inquiry, since out of nine experiments made on dogs by Nysten, in which injection was practised, in no instance was air found on the left side, although in the first, fourth, and fifth it was injected with rapidity, and death followed in a few seconds. It is true that of fatal cases which occurred during operations in the hands of Beauchêne, Dupuytren, Delpech, Castara, and Roux, in all it is stated that air was found in the arterial system excepting Delpech's, and a second case of M. Roux, the reports of which are imperfect. Out of thirty-nine experiments reported by Bouillaud, in three only was air blown into the jugular vein. The results were as follows:—

In the first it was blown in rapidly, and death occurred in two minutes; in the second it was blown in gently, and death took place in a minute and a half after the operation was over: in both cases pure blood was found on the left side of the heart. In the third instance air was blown in gently, but at two distinct periods, with an interval of three minutes, and frothy blood was found on both sides of the heart. We must except the experiments upon horses, in which the air passes more frequently to the left side of the heart, presumed to be from the larger size of the pulmonary capillaries in that animal.

From the foregoing experiments we see that when air is forcibly driven into the veins it very rarely passes the pulmonary capillaries: this points out at once the seat of obstruction; but the opinion has been entertained that the

* Précis Élémentaire de Physiologie, 8vo. 1817.

† Bulletin de l'Académie de Médecine, tome ii. 1837-1838.

cause of the weakened pulmonary circulation is to be found in the abnormal condition of the right cavities of the heart; and in support of this the sixth experiment of Nysten may be brought forward, in which, after the injection of fifty-seven centimetres* of air into the jugular vein of a small dog, the animal was restored to life by relieving the right side the heart. As it relates to the proximate cause of death I shall give the case more at length.

At the instant of injection a bruit was audible, resulting from the mixture of air and blood. Some minutes afterwards respiration ceased, the pulse was lost, and death seemed quite apparent. Nysten, then, without thinking to restore the animal to life, but intending to destroy it, cut boldly into the chest, by which the subclavian and some other veins were wounded. A considerable quantity of blood and a little air escaped, the result of which was, to his surprise, that the movements of circulation and respiration were restored; the animal recovered its effects completely; and on the third day, had it not been for the severity of the wounds, there seemed every probability of the animal surviving. At this period it was killed. No air was found in the heart, or vessels, and the lungs were healthy.

The time at which death takes place varies considerably in different cases, depending upon the amount and rapidity of injection, and the strength of the animal. From the experiments of Nysten and Cormack, it appears that when air is injected slowly, a considerable quantity may be introduced without proving immediately fatal: in some cases the animals lived a long time, and were then killed; and there is good reason for believing that a small quantity of air may pass into the veins without producing any marked consequences.

The symptoms most commonly produced by the entrance of air into the venous system in the human subject in fatal cases correspond to those of death by anæmia. Immediately after the peculiar gurgling and hissing sound, or "glouglou," has been heard, faintness supervenes, often attended with some expression of approaching dissolution, as "I die!" "I am dead!" or with anxiety and trembling, or without these; syn-

cope rapidly follows, cold sweats break out, and in a quarter of an hour, or in much less time, the patient is dead. In cases of recovery the symptoms first noted are the same; and, after a state of syncope has lasted a longer or shorter period, as the case may be, the patient regains consciousness, and the circulation is found restored.

The symptoms which have been observed in the experiments on animals differ in some respects from those just mentioned: such as a longer interval before the supervention of the symptoms, during which a peculiar churning noise is heard on ausculting the chest; a longer interval between the coming on of the symptoms and the fatal termination of the case, and also in the convulsive movements preceding death in animals. Some authors have laid great stress on this difference; but I think it need not excite much wonder; since the conditions of the two cases are so widely different; and the symptoms observed in the human subject are necessarily imperfect in many cases, from the mental anxiety of the observers, caused by the threatening dissolution of the patient.

A careful examination of the internal organs after death may assist us in some measure in our investigations to determine the mode in which the vital functions are arrested in the cases under consideration, and will also serve to remove from our minds some of the speculations which have been advanced at different times, and which, but for the negative facts furnished by a careful post-mortem examination, seem very plausible.

In nearly all the cases which have been recorded, great venous congestion has been present. The right cavities of the heart, and especially the auricle, contained air; usually also the pulmonary artery; and in some cases air was observed in the venæ cavæ: the right auricle, and in a less degree the ventricle, more or less distended, tense, and elastic, from the presence of air and blood in their cavities, the mixture being in some cases so intimate as to have given rise to the simile of "eggs beaten up for a long time, and coloured." The left side of the heart is in the majority of cases somewhat contracted, containing a small quantity of blood, and rarely any air, except in the horse. In some cases the blood and

* About three cubic inches English.

air present a frothy appearance; yet in others, not to be distinguished from these by the previous symptoms, the air and blood are unmixed in the same cavity. Sometimes the blood is fluid in both auricles and ventricles, and at other times these cavities contain clots. The lungs are observed to be quite healthy. In a few cases a condition resembling emphysema was noted, which, according to Mr. Erichsen, may have been due to the large size of the air cells in dogs, or it may have pre-existed in some horses about to be killed when unfit for other use. These are the more probable, since in the majority of cases reported no emphysema was present, even though air had been injected in many cases with as much force as possible. In all cases in which air has been found on the left side of the heart it has been present in much larger quantities on the right side. The experiments from which these facts are collected are those of Nysten, Amussat, Cornack, and Erichsen.

Instances have been cited by some experimenters in which, on exposing the heart immediately after death, its *right cavities* were found contracted and flabby. Dr. J. Reid suggests that this probably resulted from wounding some large vein in the process, though not mentioned, as it is quite at variance with the numerous and well-conducted experiments of Nysten and Amussat.

Our object will now be to ascertain, if possible, the *proximate cause of death*; for if we can accurately determine this, we stand in the most favourable position for the successful treatment of cases in which the accident before alluded to has occurred.

The opinions of various observers who have been, I may say, unfortunate enough to witness cases, differ widely. The irritation of air in the vessels of the brain,—the poisonous effects of carbonic acid gas, supposed to be elicited from the venous blood,—the over-distension of the right side of the heart,—obstruction in the pulmonary capillaries,—and a combination of three of these,—are opinions which have been respectively assigned by Bichât, Marchel de Calvi, Nysten, and Bouillaud. Piédagnel believed that death arose from emphysema of the lungs, and Sir C. Bell, that the respiratory movements ceased from destruction of the functions of the

medulla oblongata by air circulating in its vessels.

A little consideration will show the incorrectness of the theory of Bichât and Sir C. Bell. In the first place, when Nysten injected quantities of air into the carotid artery, symptoms of apoplexy came on, and death did not occur till after the lapse of some hours. Dr. John Reid also blew air into the carotids in several experiments, and found that it produced convulsions and coma, which lasted some hours before death. In the second place, the air but seldom passes to the left side of the heart. Hence, if it does not reach the brain, its presence in the cerebral vessels cannot be said to destroy the functions of this organ or the medulla.

The same course of experiments affords a refutation of the theory that carbonic acid in the blood is the cause of death. Nysten injected this gas into the vessels, and found the same results follow as when atmospheric air was thrown in, with this difference, that the gas could be found nowhere after death; but that when air was injected into the arterial system in large quantities, it was to be found throughout the vascular system as well as in the cavities of the heart. He ascertained that a small quantity of carbonic acid injected produces no visible effect.

After performing numerous experiments, it is the opinion of Mr. Erichsen that the heart is not capable of being so distended by air as to arrest its action, unless it be forcibly injected with a powerful instrument; and he questions whether this could of itself arrest the heart's action. The distension of the heart has been compared to that of the urinary bladder; but the analogy will not hold, the conditions being quite different. The bladder becomes distended gradually, and its walls rendered thereby incapable of contracting. The distension of the heart is supposed to be sudden. Furthermore, the effect of suddenly injecting large quantities of fluid into the bladder is to induce powerful contraction. I am disposed to think that the effect of a small quantity of air in the cavity of the heart is to induce at first increased action, whether owing to a spontaneous effort of the heart to get rid of the air, or to its mechanical action on that organ; and this opinion is assumed from noting in Nysten's experiments that the first oc-

currence observed by him was acceleration of the pulse and hurried respiration. With regard to emphysema, it scarcely needs alluding to. Are we to consider that this can be the cause of death, when it has only been observed in one or two experiments, and these in doubtful cases, and since death occurs with equal rapidity when the lungs are quite healthy?

That some obstruction exists in the lungs, we are warranted in concluding from the fact that in almost all the cases recorded there was fulness of the right side of the heart, and comparative emptiness of the left side; also from the constant presence of air in the right cavities where any was found, and its very rare occurrence in the left. Mr. Erichsen states that arrest to the passage of blood takes place in the capillaries of the lungs in consequence of their becoming obstructed by bubbles of air; the right auricle and ventricle becoming filled with a spumous fluid which they can neither propel forward nor drive back to any material extent, but which, oscillating in the large veins about the heart, acts as a mechanical obstacle to the passage of the blood through them; and that the animal dies as though a ligature were tied around the two cavæ; and we accordingly find after death the same congestion of blood in the venous, and absence of blood in the arterial system, that would result from such an operation.

Whether the impaired action of the heart, when it exists, is primary, and induced by the air in its cavities, or secondary, through disorder of the pulmonary circulation, I must leave for others to determine. An argument in favour of the distended condition of its cavities having some immediate influence in the production of death may be found in the fact that in many cases decided benefit has followed the free escape of blood from the wounded vessel, whether it be mixed with air or not: an experiment of Nysten's, related in the former part of this paper, is a remarkable instance, and other cases might be mentioned.

As the circulation in the lungs becomes more and more impeded, the quantity of blood which reaches the left side of the heart must be diminished; the heart itself is deprived of the necessary amount of blood through the coronary arteries; the nervous centres

do not receive sufficient oxygenated blood to maintain their functions, and the respiratory movements cease from an absence of those impressions of sensation which are necessary for the act of respiration. Mr. Erichsen, Dr. John Reid, and, as far as I am able to ascertain, all the others who have written upon this subject, have omitted mentioning an important class of cases in which the symptoms of asphyxia and coma have been most prominently marked by great lividity of the head and face approaching to blackness, convulsive movements; the respiration deep, laboured, and stertorous, and the pulse slow: two cases of this kind are reported by Dr. Warren;* another occurred to Dr. Willis, the full particulars of which I have been unable to find; and a similar case is related by Dr. Cormack.

But the presence of air-bubbles in the capillaries of the lungs, Mr. Erichsen demonstrates by experiment. He took the lungs of a dog recently killed, and found nearly double the propulsive power, ascertained by adjusting a hæmodynamometer, to drive blood through the lungs from the pulmonary artery, when air had been previously blown into the artery, than when the blood was unmixed with air. An experiment, also, of Cormack's, on a similar organ, the liver, shows the effect of air-bubbles in considerable quantities in the capillaries of that organ. After injecting air into the mesenteric vein of an animal, he found the liver in a condition of almost complete anæmia.

I must, then, infer, that obstruction to the blood in the pulmonary capillaries in the majority of instances is the immediate cause of death, and that such obstruction is occasioned by the unnatural admixture of air with the blood; but that in a few instances, where the amount of pulmonary obstruction appears to be inadequate to the production of asphyxia, the symptoms of apoplexy which present themselves lead clearly to the inference that the temporary obstruction about the heart has induced fatal cerebral congestion.

As regards the remedial measures to be adopted in cases in which air has already entered a vein; without waiting for the supervention of symptoms, an immediate indication is to prevent its

* American Cyclopædia of Practical Medicine and Surgery.

further entrance; and to effect this object the finger should be placed upon the opening whence the characteristic sound has proceeded, and then pressure applied on the thoracic side of the wound till its closure has been effected. In the further treatment we must be guided in some measure by the symptoms. If the patient becomes much collapsed, the head should be depressed, the patient placed in the horizontal posture, and no time lost in giving brandy freely. Besides the ordinary measures resorted to in cases of syncope, viz. the application of warmth in various ways, frictions, &c., it has been recommended to apply pressure upon the large arterial trunks with a view of diverting blood as much as possible to

the brain: should these means not succeed, and the respiratory powers fail, artificial respiration should be used, and kept up for at least half an hour. If, on the other hand, there is lividity of the face, laboured pulse, and stertorous breathing, blood should be abstracted from the external jugular, the effects being carefully watched, and the finger applied below the opening in the vein.

In all operations about the base of the neck and shoulders, where there is possibility of such an accident, it would be well to prevent the forcible expansion of the chest, by bandages applied around it previous to the operation, or at all events pressure should be applied on the side of the wound nearest the heart.